The Many Faces of Intracranial Arterial Dissections

T. KRINGS[1,2], I-S. CHOI[3]

[1] *Division of Neuroradiology, Department of Medical Imaging, University of Toronto, Toronto Western Hospital; Toronto, Ontario, Canada*
[2] *Service de Neuroradiologie Diagnostique et Thérapeutique, CHU Le-Kremlin-Bicêtre; Paris, France*
[3] *Interventional Neuroradiology and Cerebrovascular Disease Center, Lahey Clinic; Burlington, MA, USA*

Key words: arterial dissection, ischemia, aneurysm, giant partially thrombosed aneurysm

Summary

Intracranial arterial dissecting diseases are rare and challenging diseases with a high associated morbidity and mortality. Their common pathomechanic origin is related to blood entering the vessel wall via an endothelial and intimal tear.

Depending on the fate of the thus established intramural hematoma, different symptoms may ensue including mass effect, subarachnoid hemorrhage or ischemia. If the mural hematoma ruptures all vascular layers of the intradural artery, a subarachnoid hemorrhagic will occur. If the intramural hematoma reopens distally into the parent vessel on the other hand, ischemic embolic events may happen following intramural clot formation.

If the mural hematoma does neither open itself into the parent vessel nor into the subarachnoid space, the vessel wall may dilate leading to occlusion of perforator branches and local ischemia.

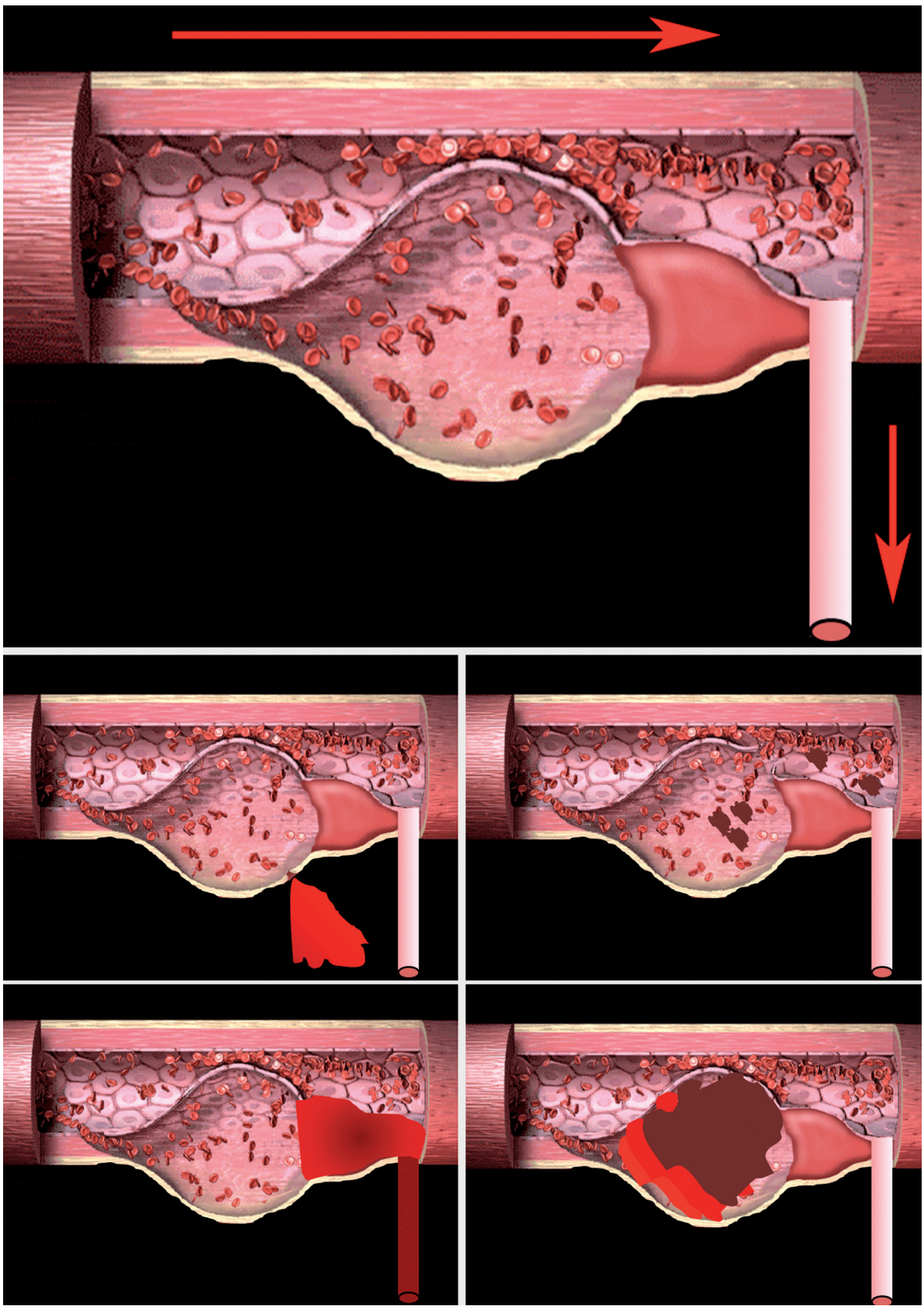
Organization of the mural hematoma may result in a chronic dissecting process which may eventually lead to formation of a "giant partially thrombosed" aneurysm with thrombus of varying ages within the vessel wall, ingrowth of vasa vasorum and recurrent dissections with subsequent growth of the aneurysm from the periphery.

Treatment strategies of these diseases should take the underlying pathomechanism into consideration and include, depending on the presentation medical treatment, parent vessel occlusion, flow reversal or diversion, surgical options or a combined treatment protocol.

Introduction

Arterial dissections are characterized by the sudden disruption of the endothelium, the intima and the internal elastic lamina with subsequent penetration of circulating blood into the media. The pathogenesis for most dissections is still unclear, and both extrinsic and intrinsic aggressive factors and defective repair mechanisms have been described to be involved in the etiology of dissections. Hypertension and smoking, but also inflammatory diseases (syphilis), and genetic predispositions, fibromuscular dysplasia, collagen disease, and trauma are found to be associated with dissections [1].

The diagnosis of a dissection is classically made by the angiographic appearance with a double lumen, a focal vessel wall irregularity, a preaneurysmal narrowing and a fusiforme dilatation. On MRI, intramural thrombus, an irregular vessel wall and a vessel wall flab can be seen. Based upon the classification of dissections by Mizutani et al. [2], different pathomechanisms can be envisioned leading to either hemorrhagic, or ischemic symptoms or symptoms related to mass effect due to a dissection. If blood enters the subintimal space due to a subintimal vessel wall tear it may have different pathologically distinct fates: 1. If the hematoma disrupts the entire vessel wall, a transmural dissection is present: Clinical symptoms will depend on the surroundings of the vessel wall: a) an intradural transmural dissection will lead to a subarachnoid hemorrhage, b) if the transmural dissection occurs in a vessel segment that is surrounded by a venous plexus (i.e. the cavernous sinus or the vertebral venous



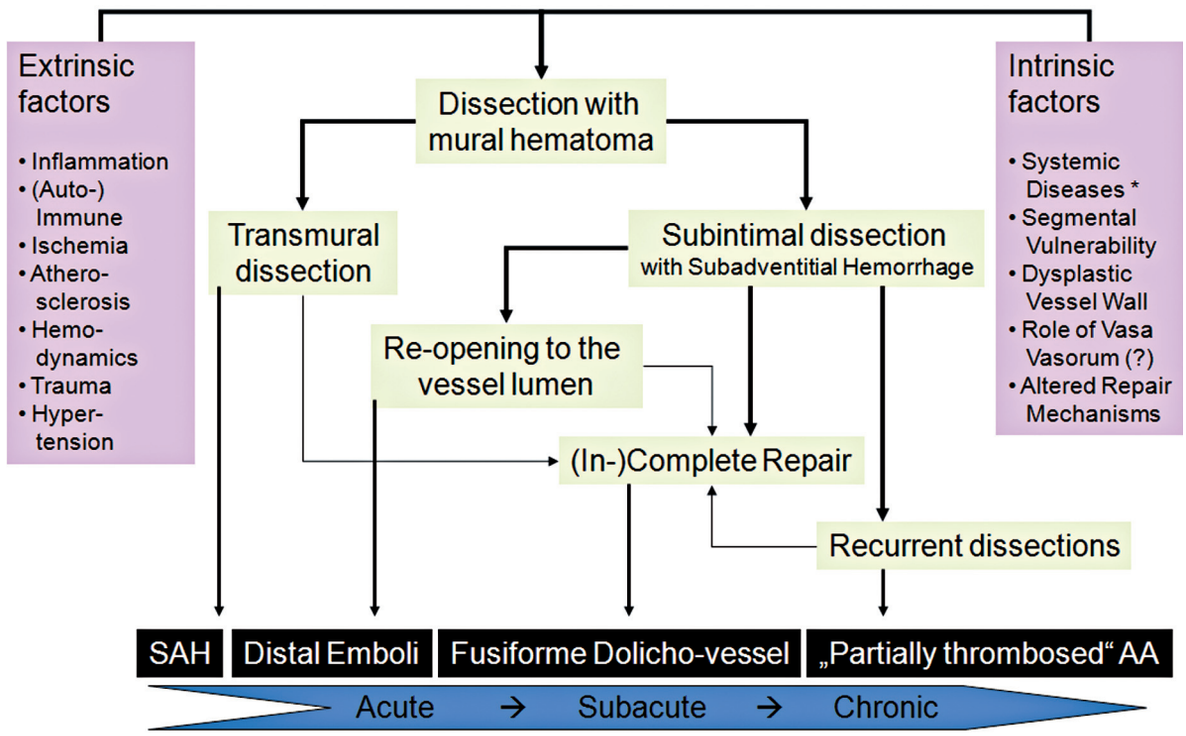


Figure 2 This schematic drawing describes what is depicted in Figure 1 adding the possibility of healing mechanisms and either complete repair or incomplete repair that may be visualized as focal dolichosegments.

plexus at the atlantal loop, an arteriovenous fistula will develop, c) if the transmural dissection occurs in soft tissues, a false aneurysm (i.e. extramural hematoma) will occur that may lead to mass effect, stenosis or occlusion of the parent vessel. 2. If the dissection remains subintimal, a subadventitial hematoma in the vessel wall will occur.

Clinical symptoms will again depend on the fate of this subadventitial hematoma: a) if there is reopening to the true vessel lumen, the hematoma (having clotted in the false lumen) can be washed out leading to distal emboli, the pathomechanism most commonly seen in adults in extradural ICA dissections, b) if the hematoma grows inside the vessel wall, the wall itself will get bigger: this can lead to a progressive stenosis of the true lumen (leading to hemodynamic infarctions or embolic events due to critical narrowing and turbulent flow), in the intradural portion, this growing hematoma can lead to occlusion of perforating branches coming off the dissected parent vessel leading to local ischemia, finally, c) if chronic, the intramural hematoma can organize in the vessel wall, vasa vasorum may sprout into the organizing hematoma and a growing intramural hematoma (due to repetitive dissections) can occur leading to the aspect of a "giant partially thrombosed aneurysm" [3]. Consequently, in dissecting diseases symptoms can be related either to mass effect, ischemia, or subarachnoid hemorrhage, or, in rare cases in a combination of different presenting symptoms [4,5] (Figures 1 and 2).

← *Figure 1* This schematic representation describes the different pathomechanisms of intradural arterial dissecting diseases. In the upper row an intradural vessel with a distal perforator is depicted. Blood enters the subintimal space due to a endothelial and intimal defect leading to intramural hematoma. Depending on the fate of this intramural hematoma, at least four different pathomechanisms are depicted below. If the hematoma disrupts the entire wall (middle row, left panel), blood enters the subarachnoid space leading to a hemorrhagic dissection and SAH. If the mural hematoma re-enters the parent vessel further distally (middle row, right panel), distal embolic events can occur. If the hematoma expands (lower row, left panel) local perforators can be occluded leading to local ischemia. Finally, if the hematoma organizes itself, recurrent dissections may occur leading to thrombus of varying ages within the vessel wall and the phenotypic expression of a "partially thrombosed" giant aneurysm.

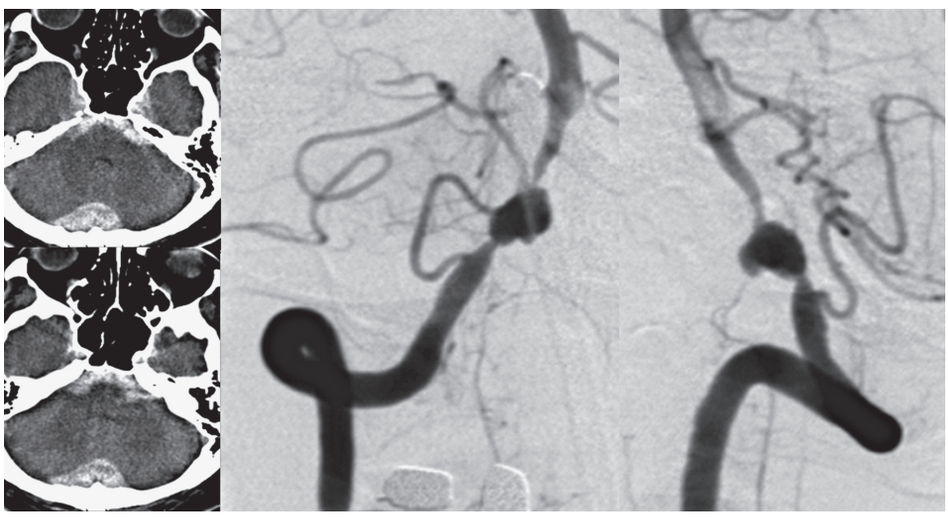


Figure 3 Hemorrhagic dissection of the right vertebral artery with the classical appearance of a fusiforme dissecting aneurysm with preceeding narrowing of the lumen.

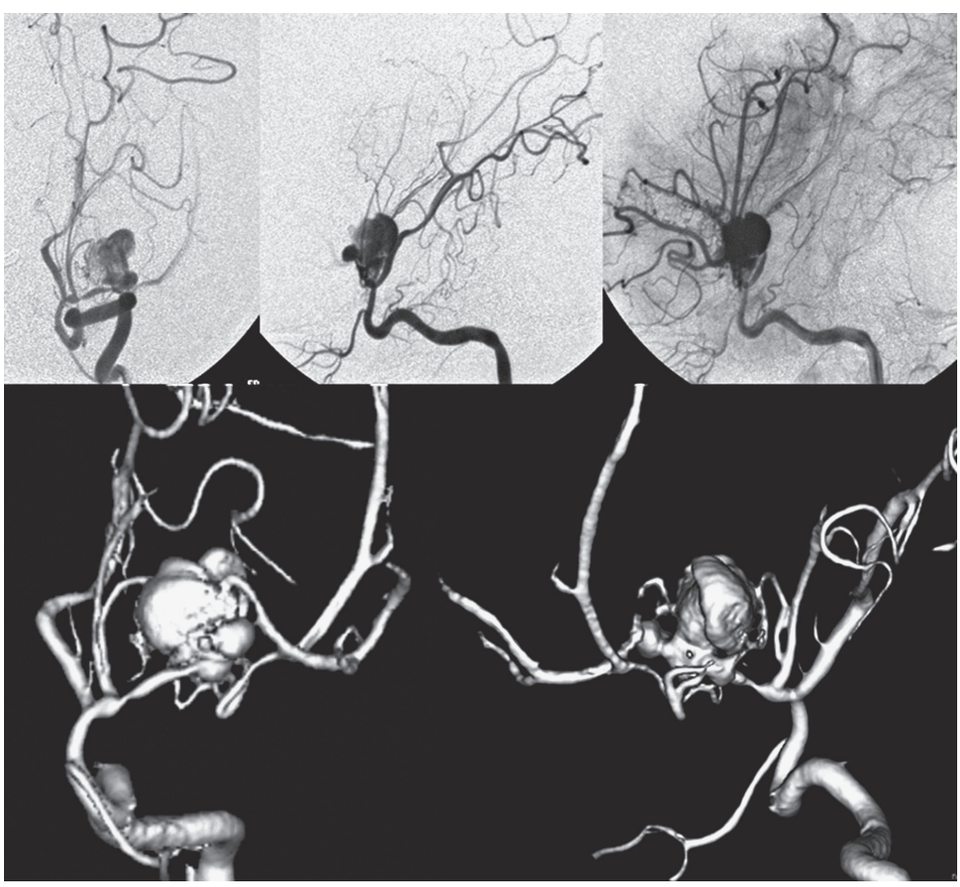


Figure 4 Hemorrhagic dissection of the middle cerebral artery.

Dissections and Subarachnoid Hemorrhage

Subarachnoid hemorrhage (SAH) from spontaneous transmural dissection involving the intradural arteries is presumably the most common presenting symptom. Approximately 1-10% of all non-traumatic SAH are related to a hemorrhagic dissection in the adult population, in the pediatric agegroup, however, they represent one of the most common causes of SAH. They are more common in the posterior circulation compared to the anterior circula-

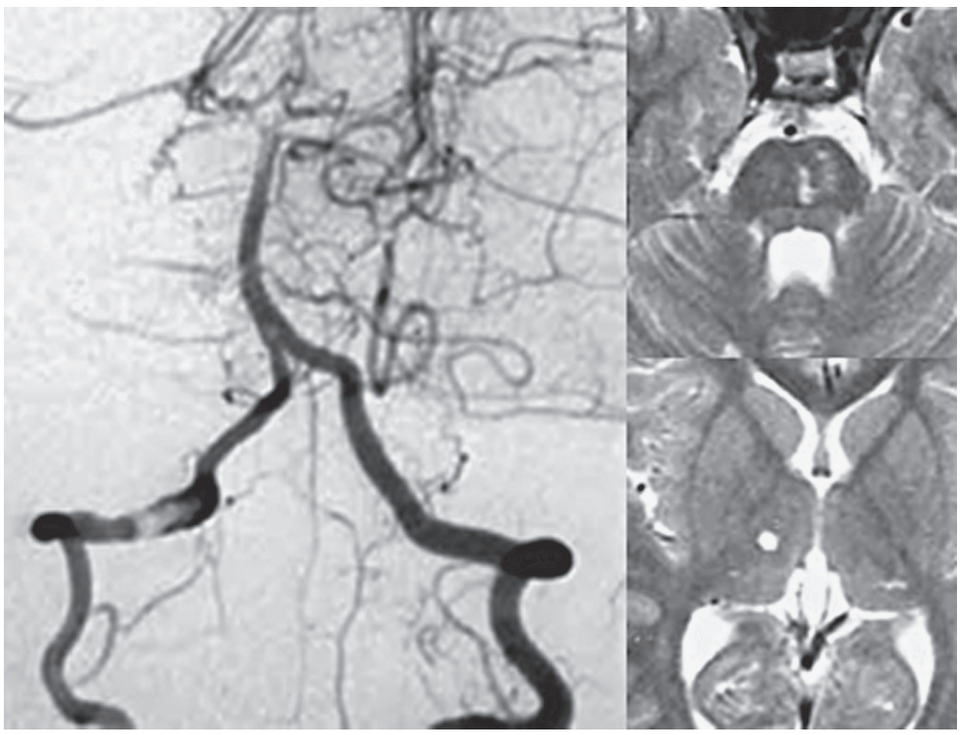


Figure 5 This patient presented with sudden onset of headaches and neurological symptoms suggestive of posterior fossa ischemia. T2 weighted sequences demonstrate multiple foci of ischemia in the brainstem and the thalamus, the vertebral artery injections demonstrates a focal, narrowing and luminal irregularity of the right vertebral artery as the most likely source of the patient's emboli.

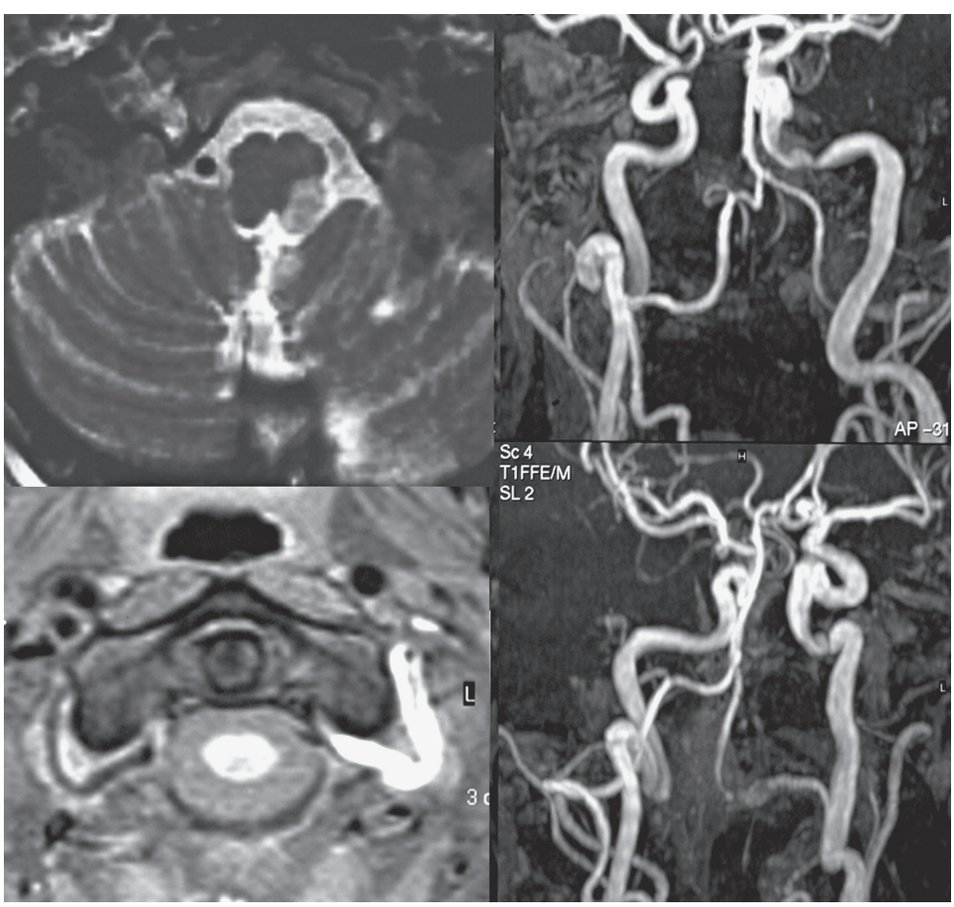


Figure 6 Focal perforator ischemia with infarction of the dorsolateral medulla oblongata on the left. Notice the missing flow void on the left vertebral artery and the evidence for the mural hematoma within the intra- and extradural left vertebral artery.

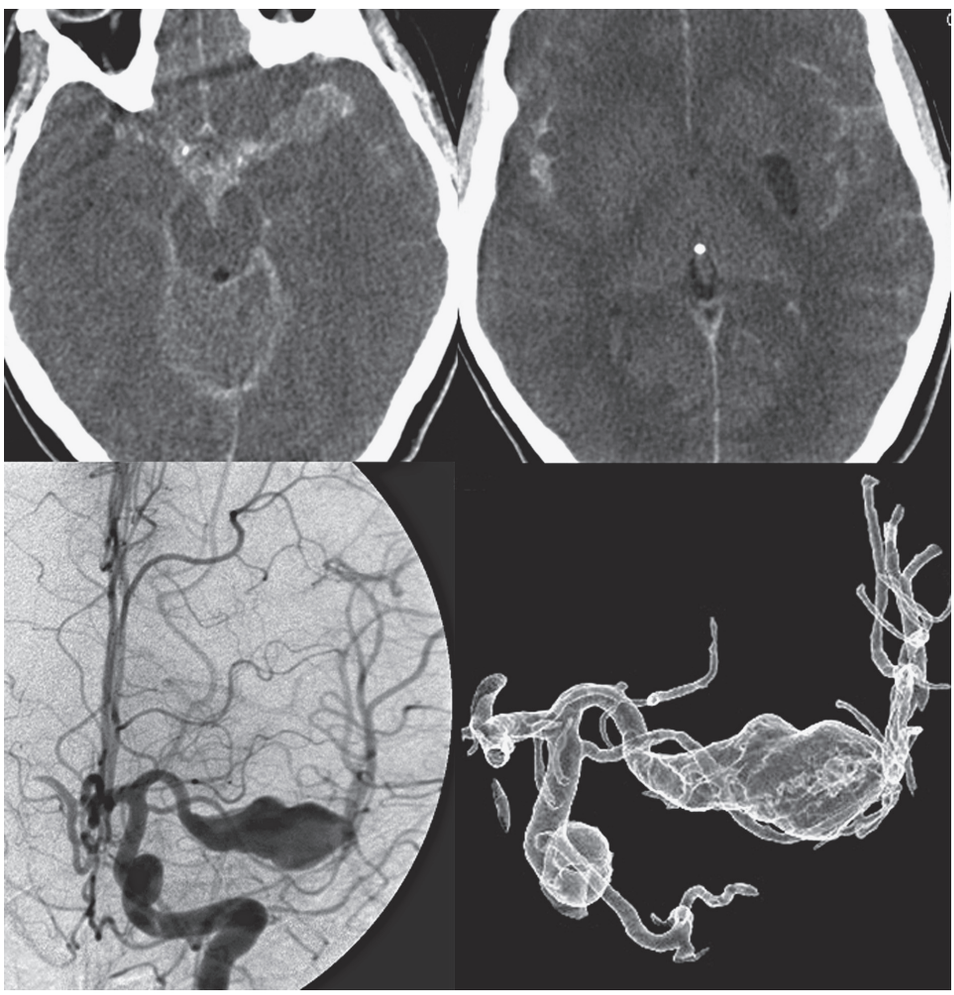


Figure 7 Different pathomechanisms can coexist in dissecting diseases: This patient presented with a deep perforator stroke, he developed a subarachnoid hemorrhage over the course of a few days indicating perforator ischemia due to expansion of an intramural hematoma followed by transmural rupture.

tion presumably since the intradural vertebral artery has a thin media with fewer elastic fibers [6]. The most frequent angiographic demonstration is regular or irregular fusiform dilatation preceded by a stenotic segment (that represents the proximal start of the dissection) (Figures 3 and 4).

According to the classification proposed by Mizutani, they are the type I dissections with disruption of the internal elastic lamina, no intimal thickening and a pseudolumen opening to the surrounding subarachnoid space without reentry into the true lumen [2]. Acutely ruptured dissections are unstable and have a tendency to rebleed in the acute phase with up to 70% of rebleeds in the first 24 hours, 80% of rebleeds in the first week and only 10% of rebleeds after one month [7].

The mortality rate of these re-bleeds is nearly 50%. In our practice, we base our treatment decision on this natural history with treatment of acute dissections (by parent vessel sacrifice or flow reversal) and a more conservative management when the patient is referred to us in the subacute stage (i.e. one month or later after the dissection occurred).

The aim of treatment in the acute phase is to secure the patient from rehemorrhage [8], taking into consideration that the disease process starts proximal to the fusiformely dilated vessel segment and more often than not is characterized by a focal narrowing of the vessel that pinpoints the entry point of the blood into the vessel wall. Pseudoaneurysm coiling only may therefore lead to periprocedural or belated rehemorrhage since the dissected vessel wall is not completely excluded from the circulation. Stenting with subsequent coiling in the acute setting is dangerous since the patient has to be put under aggressive antiaggregation in the acute phase of a transmural hemorrhage and early rebleeding may occur if the dissection is

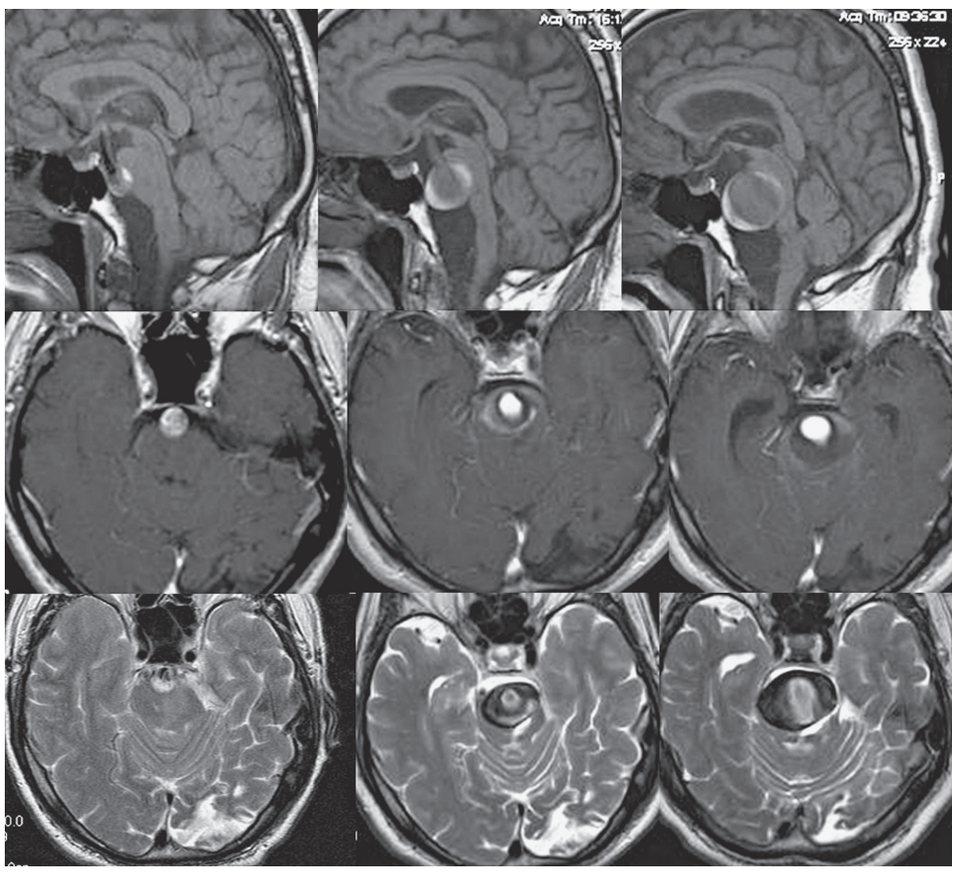


Figure 8 Unenhanced sagittal T1 weighted sequences, enhanced axial T1 weighted sequences and axial T2 weighted sequences at three timepoints over the course of 6 years. These pictures demonstrate the subsequent growth of a fusiforme partially thrombosed giant aneurysm of the basilar artery with mural hematoma (methemoglobin signal on T1 weighted sequences) in the periphery of the aneurysm and subsequent mass effect on the brain stem.

not completely cured [9]. When contemplating to preserve the vessel with these techniques the pathomechanism has to be kept in mind: coiling of the dissected segment following stent protection may lead to deposition of coils into the subarachnoid space due to the transmual dissection with fatal rehemorrhage. The densely woven mesh of current flow diversion stents may constitute a treatment alternative since this mesh may help in pushing the dissection flap back against the wall thereby preventing further progression of the dissection. However, long-term results concerning neointimal hyperproliferation, especially in the pediatric age group are not yet available. This is why we still opt in most instances for a parent vessel occlusion with occlusion of the dissected segment or flow reversal.

While in neonates and infants the leptomeningeal collateral supply is usually sufficient to prevent from subsequent ischemia, this treatment may have to be preceded by surgical distal bypasses in adults when collateral circulation is deemed insufficient [4].

Dissections and Ischemia

A second potential presenting symptom of a dissection is ischemia that can be either related to distal emboli (predominantly in extradural and only rarely in intradural dissections – that may be due to stenosis or reopening of the dissection into the true lumen) or local perforator occlusion (in intradural dissections with mural hematoma) (Figures 5 and 6). On angiography, either intra- or, more commonly, extradural dissections are perceived. The angiographic appearance is that of an acute stenosis that is related to the intramural hemorrhage compressing the true vessel. On cross-sectional imaging, this intramural hematoma can be perceived in

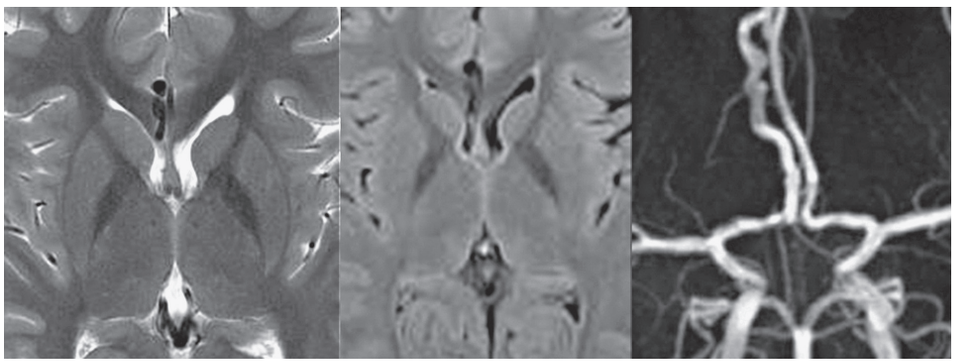


Figure 9 An incompletely healed dissection can resemble a focal dolichosegment. If no wall disorder is visualized as in this example, these dolichosegments are followed conservatively.

the acute stages of an dissection as a crescent shaped hyperintensity in the vessel wall on T1 weighted fat-suppressed images [10]. If there is reentry of the dissection into the true lumen, clot may dislodge and lead to distal emboli, however, embolic events may also occur due to thrombus formation within the stenotic vessel, hemodynamic infarctions are rare, especially in the posterior circulation [11].

Intradurally, the mural hematoma may involve perforators and thereby occlude them. Treatment of these dissections is challenging and depends on the presumed pathomechanism: In embolic strokes it is presumed that acute anticoagulation or antiaggregation presents the best treatment option to prevent secondary embolic events [12]. If perforator occlusion however is suspected, one may contemplate proximal parent vessel occlusion to prevent further mural expansion by the inflowing and trapped blood.

Perforator occlusion has to be considered if ischemia is present in the territory of local perforators at the site of the dissection [13]. If in these patients under conservative therapy a secondary stroke was to occur and imaging was to show expansion of the intramural hematoma, we would suggest parent vessel occlusion to stop the blood from entering the dissection cavity. If hemodynamic strokes were present in the setting of an insufficient circle of Willis and a high grade stenosis due to the dissection, a stenting procedure to enhance distal bloodflow may have to be considered.

In rare instances ischemic and hemorrhagic presentations may occur simultaneously, in these instances, expansion of the wall leading to perforator ischemia AND subsequent transmural dissection leading to SAH are present (Figure 7).

Dissections and "Giant Partially Thrombosed" Aneurysms

The third presenting pathomechanism of dissecting diseases is the so called "giant partially thrombosed aneurysm". Histological examinations of thrombosed giant aneurysm demonstrate more recent hemorrhage between old thrombus and the aneurysm wall with clefts of fresh blood present, indicative of a dissection of the aneurismal wall by blood flow [14,15]. This theory is further corroborated by studies that describe organized laminar thrombus with evidence for a dissection of the vessel wall [2]. In the so-called type 3 dissecting aneurysms according to the Mizutani classification fragmentation of the internal elastic lamina combined with multiple dissections of the thickened intima and repetitive thrombus formation at the site of intimal dissection is found. These histologiocal findings are further backed by imaging studies that suggest that the formation of intracranial partially thrombosed giant artery aneurysms is due to a subacute recurrent dissection processes with repeated subadventitial haemorrhages [16,17]. In the vast majority of patients with partially thrombosed aneurysms, a hyperintensity on non-enhanced T1-weighted images indicative of fresh hemorrhage is present within the thrombus along the aneurismal wall and away from the patent lumen [18]. An enhancing rim can be perceived with perifocal edema and an onion-skin appearance of a multilayered thrombus wall is present [3,19]. From a clinical point of view, these aneurysms rarely present with subarachnoid hemorrhage, but rather lead to mass effect due to repetitive intramural hemorrhages (as identified by a methemoglobin rim distant from the perfused lumen in the outer vessel wall,

perifocal edema and an onion skin appearance of the intramural hematoma suggesting blood of varying ages and subsequent growth over time) [20-22] (Figure 8). Treatment of these lesions is probably the greatest challenge of all dissecting processes since they may be regarded as a proliferative disease of the vessel wall with growth induced by extravascular activity. It has been demonstrated that these aneurysms can regrow even following parent vessel occlusion [20,23]. A purely endoluminal treatment is unlikely to stop the disease process, either, since in those patients treated with coils, aneurysms will regrow over time, maybe due to coil compaction maybe due to the fact that the pathological process is maintained in the vessel wall [24]. Ideal treatment should be complete surgical excision of the lesion, however, this procedure might only be possible after distal and proximal vessel wall occlusion (trapping) which might not be tolerated by the patient depending on the location of the aneurysm. Apart from medical, i.e. anti-inflammatory treatment (such as steroids), one might also consider parent vessel occlusion, flow reversal to stop the dissecting process or remodelling of the vessel employing curative reconstruction devices (flow diverters) with dense stent meshes.

Dissections and Healing Processes

If left untreated, the histopathologic healing response involves covering of the entire area of the disrupted arterial wall with neointima. Vessel wall healing occurs from the disrupted ends of the media toward the ruptured portion. The healing mechanism may be delayed under several conditions such as aneurysms with extensive defects of the aneurysmal wall in the ruptured portion (i.e. large aneurysms), aneurysms with abundant thrombus in the ruptured portion (since neointima may appear in accordance with retraction of the thrombus), or aneurysms in which the media is completely separated from the adventitia [25]. In addition, in underlying vessel wall diseases the healing response may be insufficient. In cases where the patient survives the acute dissection without treatment, once the dissection has entered into a chronic stage, either complete repair of the vessel or an incomplete repair may therefore be observed. An insufficient healing may lead to the formation of focal fusiforme outpouchings (Figure 9) that can be differentiated from serpentiforme partially thrombosed aneurysms by their areactive (thin) vessel wall without evidence for thrombus formation in the vessel wall. This incomplete repair is followed conservatively.

References

1 Yamada M, Miyasaka Y, Yagishita S, et al. Dissecting aneurysm of the intracranial vertebral artery associated with proximal focal degeneration of the elastica: a comparative pathological study of the vertebral artery in patients with and without aneurysms. Surg Neurol. 2003; 60: 431-437.
2 Mizutani T, Miki Y, Kojima H, et al. Proposed classification of nonatherosclerotic cerebral fusiform and dissecting aneurysms. Neurosurgery. 1999; 45: 253-259; discussion 259-260.
3 Krings T, Alvarez H, Reinacher P, et al. Rupture mechanisms of partially thrombosed aneurysms. Interventional Neuroradiology. 2007; 13: 117-126.
4 Krings T, Geibprasert S, Terbrugge K. Pathomechanisms and treatment of pediatric aneurysms. Childs Nerv Syst. 2010; in press.
5 Kim CH, Son YJ, Paek SH, et al. Clinical analysis of vertebrobasilar dissection. Acta Neurochir (Wien). 2006; 148: 395-404.
6 Endo S, Nishijima M, Nomura H, et al. A pathological study of intracranial posterior circulation dissecting aneurysms with subarachnoid hemorrhage: report of three autopsied cases and review of the literature. Neurosurgery. 1993; 33: 732-738.
7 Mizutani T, Kojima H. Clinicopathological features of non-atherosclerotic cerebral arterial trunk aneurysms. Neuropathology. 2000; 1: 91-97.
8 Peluso JP, Van Rooij WJ, Sluzewski M, et al. Endovascular treatment of symptomatic intradural vertebral dissecting aneurysms. Am J Neuroradiol. 2008; 29: 102-106.
9 Yonas H, Agamanolis D, Takaoka Y, et al. Dissecting intracranial aneurysms. Surg Neurol. 1977; 8: 407-415.
10 Wessels T, Mosso M, Krings T, et al. Extracranial and intracranial vertebral artery dissection: long-term clinical and duplex sonographic follow-up. J Clin Ultrasound. 2008; 36: 472-479.
11 Schievink WI, Mokri B, Piepgras DG. Spontaneous dissections of cervicocephalic arteries in childhood and adolescence. Neurology. 1994; 44: 1607-1612.
12 Arnold M, Bousser MG, Fahrni G, et al. Vertebral artery dissection: presentation findings and predictors of outcome. Stroke. 2006; 37: 2499-2503.
13 Songsaeng D, Srivatanakul K, Krings T, et al. Symptomatic Spontaneous Vertebrobasilar Dissections in Children: Review of 29 consecutive patients. J Neurosurg. 2010; in press.
14 Yasui T, Sakamoto H, Kishi H, et al. Rupture mechanism of a thrombosed slow-growing giant aneurysm of the vertebral artery - Case report. Neurol Med Chir (Tokyo). 1998; 38: 860-864.
15 Nagahiro S, Takada A, Goto S, et al. Thrombosed growing giant aneurysms of the vertebral artery: growth mechanism and management. J Neurosurg. 1995; 82: 796-801.
16 Schubiger O, Valavanis A, Hayek J. Computed tomography in cerebral aneurysms with special emphasis on giant intracranial aneurysms. J Comput Assist Tomogr. 1980; 4: 24-32.
17 Schubiger O, Valavanis A, Wichmann W. Growth-mechanism of giant intracranial aneurysms; demonstration by CT and MR imaging. Neuroradiology. 1987; 29: 266-271.
18 Koyama S, Kotani A, Sasaki J. Giant basilar artery aneurysm with intramural hemorrhage and then disastrous hemorrhage: Case report. Neurosurgery. 1996; 39: 174-177.
19 Teng MM, Qadri SMN, Luo CB, et al. MR imaging of giant intracranial aneurysm. J Clin Neurosci. 2003; 10: 460-464.
20 Krings T, Piske RL, Lasjaunias PL. Intracranial arterial aneurysm vasculopathies: targeting the outer vessel wall. Neuroradiology. 2005; 47: 931-937.
21 Kaneko T, Nomura M, Yamashima T, et al. Serial neuroimaging of a growing thrombosed giant aneurysm of the distal anterior cerebral artery - case report. Neurol Med Chir (Tokyo). 2001; 41: 33-36.
22 Katayama Y, Tsubokawa T, Miyazaki S, et al. Growth of totally thrombosed giant aneurysm within the posterior cranial fossa. Diagnostic and therapeutic considerations. Neuroradiology. 1991; 33: 168-170.
23 Iihara K, Murao K, Sakai N, et al. Continued growth of and increased symptoms from a thrombosed giant aneurysm of the vertebral artery after complete endovascular occlusion and trapping: the role of vasa vasorum. Case report. J Neurosurg. 2003; 98: 407-413.
24 Van Rooij WJ, Sluzewski M. Endovascular treatment of large and giant aneurysms. Am J Neuroradiol. 2009; 30: 12-18.
25 Zhao WY, Krings T, Alvarez H, et al. Management of spontaneous haemorrhagic intracranial vertebrobasilar dissection: review of 21 consecutive cases. Acta Neurochir (Wien). 2007; 149: 585-596; discussion 596.

Prof. Dr. T. Krings, FRCP (C)
University of Toronto
Toronto Western Hospital, UHN
Division of Neuroradiology
399 Bathurst St., 3MCL - 429
Toronto, ON, M5T 2S8, Canada
Tel.: 001 416-603-5266
Fax: 001 416-603-4257
E-mail: timo.krings@uhn.on.ca